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DUANE ARNOLD ENERGY CENTER
CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY

ANNUAL REPORT

January 1986 - December 1986

Submitted by

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 13th year of station operation (January 1986 to December 1986).

The Duane Arnold Energy Center Operational Study was implemented in mid-January 1974. Prior to plant start-up, extensive pre-operational data were collected, from April 1971 to January 1974. These pre-operational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of 13 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, about two and one-half miles north-northeast of Palo, Iowa, in Linn County.

The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers, which require a maximum of 11,000 gpm (about 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (about 15.5 cfs) may be lost through evaporation, while 4,000 gpm (about 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These pre-operational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water, and were first implemented in January 1974.[4-15]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.

2. To conduct physical, chemical, and biological studies in and adjacent to the discharge canal and to compare the results with similar studies above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities adjacent to the discharge.

STUDY PLAN

During the operational phase of the study, sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): (1) Upstream of the plant at the Lewis Access Bridge (Station 1), (2) directly upstream of the plant intake (Station 2), (3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3), and (4) adjacent to Comp Farm, about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering, University of Iowa. From January 1979, through December 1983, samples were collected and analyzed by Ecological Analysts, Inc. Since 1984, collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analysis.

Samples for routine chemical, physical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

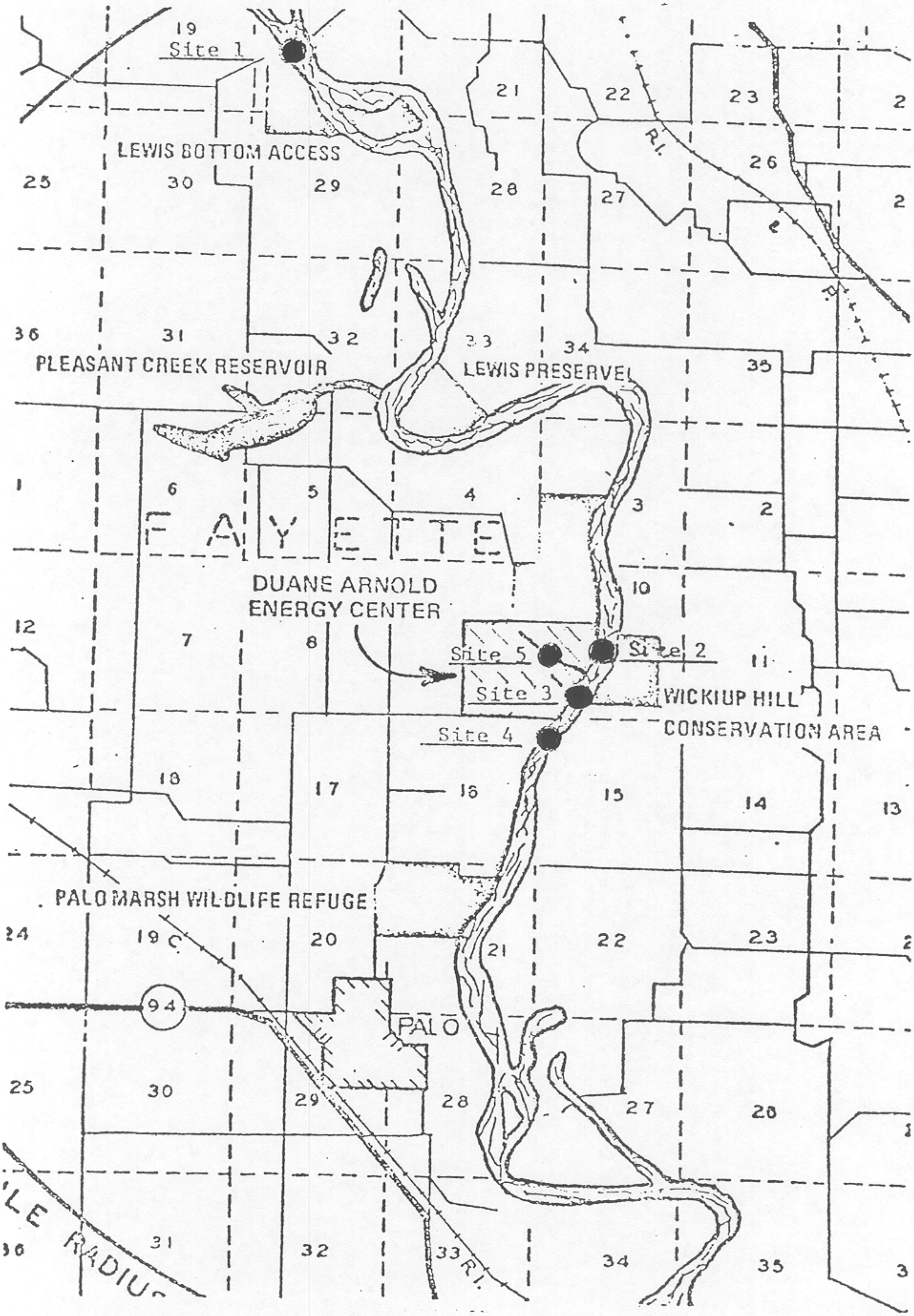

Figure 1. Location of Operational Sampling Sites

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved and suspended)
4. Dissolved Oxygen
5. Carbon Dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical Oxygen Demand
14. Coliform series (total and fecal)

II. Additional Chemical Determinations

A. Frequency: spring, summer, and fall

B. Location: at all five stations

C. Parameters measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic studies

1. Frequency: summer and fall

2. Location: at all five stations

B. Impingement studies

1. Frequency: daily

2. Location: intake structure

C. Asiatic Clam (Corbicula) survey

1. Frequency: three times yearly

2. Location: upstream and downstream of the plant intake bay, and cooling tower basin

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

Mean monthly flows in the Cedar River during the period January-December 1986, were consistently above the median, ranging from 707% of the median monthly discharge in October to 132% in August. During 1986, flows were considerably higher than those of 1985. Estimated mean flow for the year was ca. 6,475 cfs, the sixth highest mean flow observed during the 1972-1986 period and substantially above the 15 year average flow of ca. 5,200 cfs. Mean monthly discharges at the Cedar Rapids gauging station ranged from 2,466 cfs in January to 10,612 cfs in May. Mean monthly discharges in 1986 were classified as excessive (greater than the 75% quartile) in all but three months (February, April, and August). Winter flows varied from ca. 1,840 to 3,600 cfs until early March and then rose rapidly to a yearly high of 32,100 cfs on March 24, 1986. Flows generally declined from late March through April to ca. 5,200 cfs, but increased to over 17,000 cfs in mid-May. Summer flows ranged from ca. 3,800 to 15,000 cfs in June and July, falling to ca. 2,000 cfs by late August. Flow increased in late September and October, reaching a fall maximum of 22,000 cfs on October 18. Discharge was substantially lower during November and December, ranging from 6,170 to 1,840 cfs. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient river temperatures during the period ranged from 0.0°C (32.0°F) to 26°C (78.8°F). The maximum ambient temperature observed upstream of the plant (Stations 2 and 3) on July 22 was somewhat lower than those of previous years. The maximum downstream temperature of 27°C (80.6°F) was observed in the mixing zone (Station 3) on the same date. The highest discharge canal (Station 5) temperature observed during the period, 31°C (87.8°F), was recorded on July 8. The Duane Arnold Energy Center was on-line throughout most of 1986, but because of relatively high river flows, temperature differentials between upstream and downstream river locations were minimal. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 18°C (32.4°F) was observed on January 14.

Maximum ΔT values between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 4°C (7.2°F), were also measured on January 14 and February 25. The maximum temperature elevation at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) of 4°C (7.2°F) was also observed on January 14. This was the only instance in which a temperature elevation in excess of the Iowa Water Quality Standard was observed.[16] No other samples taken at Stations 3 or 4 exhibited temperature differentials in excess of 1°C (1.8°F). A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

<u>Turbidity</u> (Table 4)

In spite of high river flows, turbidity values were similar to those of the previous year, likely due to higher river discharge. Peak values of 160-180 NTU occurred at all river locations during late June. Turbidity values in the discharge canal were frequently slightly higher than those observed in river samples. A maximum discharge canal turbidity of 340 NTU was also observed on June 24.

<u>Solids</u> (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples exhibited little variation during the year. Values ranged from 300 to 640 mg/L, with the majority falling between 350 and 450 mg/L.

Dissolved solids values were relatively low throughout the period. Upstream values ranged from 210 mg/L during a period of increasing river flow in March, to 420 mg/L in October. Dissolved solids values at Station 3, 140 feet downstream of the discharge canal, were somewhat higher than values observed upstream of the discharge canal. A maximum downstream value of 540 mg/L was observed at Station 3 on July 22. Dissolved solids values at Station 4, one-half mile below the plant, were occasionally slightly higher than upstream levels.

Suspended solids values in the river were relatively low, ranging from <1 to 280 mg/L. Low values occurred in February, while high values occurred in June.

Due to concentration in the blowdown, total and dissolved solids values in the discharge canal were consistantly higher than in the river samples. Maximum total solids concentrations of 1,800 mg/L were observed in the discharge canal in July, while a minimum value of 370 mg/L was observed on March 25 when the station was not operating.

Chemical Conditions

<u>Dissolved Oxygen</u> (Table 8)

Dissolved oxygen concentrations in river samples collected during 1986 ranged from 7.4 to 15.7 mg/L (86 to 111% saturation).

Overall, concentrations in the river were somewhat lower than those observed in 1985, and in contrast to the previous year, were rarely in excess of saturation from April through September. A maximum oxygen saturation value of 132% was observed upstream of the plant on August 19. Unlike the previous year, high dissolved oxygen concentrations associated with photosynthetic activity were not commonly observed. This is not surprising considering the higher river flows present in 1986, which probably reduced algal activity.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 6.2 to 15.6 mg/L. Lowest values occurred during periods of highest temperatures, while high concentrations were observed in the late fall and winter.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations ranged from <1 to 40 mg/L. As in previous years, highest values frequently occurred during the winter period, while values of <1 mg/L occurred at intervals from April through early September.

Alkalinity, pH, Hardness (Tables 10-14)

These closely related parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Total alkalinity values in river samples ranged from 124 to 244 mg/L. Low values occurred in early March during spring runoff, and surprisingly, during a low flow period in August. High values occurred during the winter months.

Carbonate alkalinity was observed at intervals in river samples in April and early May, and in July and September, at levels ranging from 6-12 mg/L. This was in contrast to 1985, when carbonate alkalinity persisted in the river throughout the summer. The absence of carbonate alkalinity appeared to be related to the higher river flows and subsequent reduction of photosynthetic activity during the summer of 1986.

Values for pH in river samples exhibited less variation than those observed in 1985, ranging from 7.1-7.2 in January and March to 8.7 in July. As in previous years, high values usually coincided with periods of increased photosynthetic activity. pH values in the discharge canal ranged from 7.3 to 9.2.

Total hardness values in the upstream river generally paralleled total alkalinity levels. The highest values (325-350 mg/L) occurred during the winter, while low values of ca. 180-190 mg/L occurred in early March. Hardness values in the discharge canal were consistently higher than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 205 to 979 mg/L. Levels downstream of the station were similar to upstream values because of high river flow during 1986.

Calcium hardness levels were substantially lower than total hardness values but exhibited similar variations. Values ranged from 110 to 295 mg/L in river samples, and from 115 to 635 mg/L in the discharge canal.

<u>Phosphates</u> (Tables 15 and 16)

In general, total phosphate concentrations in upstream river samples were slightly lower than those observed during 1984 and 1985. Ambient concentrations in the river ranged from 0.15 mg/L in

April to 0.51 mg/L in June, during a period of rainfall and increasing runoff. Levels in the discharge canal were frequently higher than those observed in the river. A maximum value of 1.4 mg/L was observed in the discharge canal in November. Phosphate concentrations in the mixing zone were occasionally higher than those observed upstream.

Orthophosphate concentrations in river samples ranged from <0.01 mg/L in April and August to a maximum value of 0.32 mg/L in July. As in previous years, orthophosphate concentrations were lower than total phosphate levels. The greatest differential between total and orthophosphate concentrations coincided with large plankton populations and the resultant uptake of orthophosphate.

Ammonia (Table 17)

Average ammonia nitrogen concentrations in the river were relatively low during 1986 and were comparable to values observed since 1983. Concentrations ranged from <0.01 to 0.48 mg/L. As in previous years, highest concentrations accompanied snowmelt and high flows in late winter and early spring. Low values of 0.02 mg/L or less were observed at intervals from April to early November.

Nitrate (Table 18)

The trend to lower nitrate concentrations observed in 1984 and 1985 appears to have been reversed during 1986. During the current year, nitrate values in river samples ranged from ca. 2.4 mg/L (as N) in August and September to 11.0 mg/L (as N) in early July. The average nitrate nitrogen concentration at Station 1, located at Lewis Access upstream of the plant, was 6.8 mg/L, 2 mg/L higher than the

1985 average. Nitrate concentrations equal to or in excess of the 10 mg/L (as N) EPA drinking water standards[17] were observed in the river in May and July. Concentrations of less than 3 mg/L (as N) were observed in August and September, when river flows were relatively low. Nitrate concentrations were frequently higher in the discharge canal than in river samples, due to reconcentration in the blowdown. Maximum nitrate nitrogen concentrations of 21 mg/L were observed in the discharge canal in July.

Iron (Table 19)

Maximum iron concentrations in the river were substantially lower than those observed in 1985. Concentrations in river samples in 1986 ranged from 0.09 to 1.6 mg/L. Highest concentrations occurred in March, June, and October in conjunction with increasing river flow. Low values of 0.2 mg/L or less occurred during the winter. As in previous years, high iron concentrations were usually observed in association with high turbidity and suspended solids values, indicating that most of the iron present is in the suspended form rather than in solution. Iron levels were frequently higher in the discharge canal than in river samples. A maximum iron value of 2.9 mg/L was observed in the canal in June.

Biological Conditions

Biochemical Oxygen Demand (Table 20)

Average five-day biochemical oxygen demand (BOD_5) values were substantially lower than those observed in 1985. Levels in the river ranged from <1 to 12 mg/L. Relatively high values (6-8 mg/L) were associated with the beginning of runoff in March, but otherwise the winter and early spring period was characterized by low BOD levels of 3 mg/L or less. High BOD values, ranging from 6 to 12 mg/L, were consistently observed in August and September, when river flows were relatively low and larger algal populations were present.

<u>Coliform Organisms</u> (Tables 21 and 22)

Determination of total and fecal coliform bacterial populations was reinstituted in 1984 after being discontinued in 1978. In spite of higher river flows, average coliform values were similar to those observed during 1985, but appeared to exhibit less variation than those of the previous year. Highest counts occurred during periods of increasing river flow in June and October. A maximum total coliform count of 12,000 organisms/100 ml was observed upstream at the Lewis Access location on October 7, while the maximum observed fecal coliform level, 3,000 organisms/100 ml, was observed 1/2 mile downstream of the station on June 24. Low total coliform counts of 100 to 500 organisms/100 ml were observed during periods of relatively low flow in August and September, and during a period of very high flow in March. Minimum fecal coliform concentrations of 10 to 40 organisms/100 ml were observed in late April and early May.

There appeared to be little difference between coliform densities upstream and downstream of the station.

ADDITIONAL STUDIES

In addition to the routine monthly studies, a number of seasonal limnological and water quality investigations were conducted during

1986. The studies discussed here include additional chemical determinations, benthic and impingement studies, and an Asiatic clam (Corbicula) survey.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 8, July 22, and November 4 and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. In general, concentrations fell within the expected ranges and were similar to those observed during the previous year.

Concentrations of most heavy metals in the 1986 samples were, in general, relatively low throughout the year. Two samples collected upstream and downstream of the plant (Stations 2 and 3) on November 4 equaled or were slightly in excess of the Iowa Water Quality Standard for copper.[16] The highest concentration (30 ug/L) was observed at the upstream location. No other violations of water quality standards were observed. In general, little variation was present between locations. The relatively high manganese levels (950 mg/L) observed upstream of the plant (Station 1) in 1985 were not apparent in the 1986 samples. Values for other heavy metals were usually below the detection limit. Concentrations of chloride and sulfate were within the expected ranges.

Reconcentration of solids in the cooling tower blowdown resulted in slightly elevated chloride, and some heavy metal concentrations in the discharge canal samples. High sulfate levels were observed in the discharge canal and within the mixing zone (Station 3) on July 22 and November 4, due to the addition of sulfuric acid for pH control in the cooling water. The results of the additional chemical determinations are given in Table 23.

Benthic Studies

Bottom samples were taken at two locations, upstream and downstream of the station, in May and October, 1986, by means of a Ponar dredge. No organisms were found in the October samples and only three chironomid larvae were found in the May samples. Although these numbers appear extremely low, they are compatible with earlier studies that indicated the shifting sand and silt bottom supports a benthic community of very limited size and diversity.

Three artificial substrates (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station, and in the discharge canal in May and October. These substrates were collected in June and November, following a six-week colonization period. Only six of the original 15 substrates were recovered from the Cedar River following colonization in June, and only four of the 15 in November. The poor recovery rate was probably the result of unseasonably high river flows. As in previous years, substrate samples were characterized by greater numbers and species diversity than the natural substrate (Ponar dredge) samples. A total of 24 taxa were identified during the two sampling periods; 23 in June and 14 in November. No major seasonal differences were apparent. Discharge canal samples were dominated by mayfly (ephemeroptera) nymphs and midge (chironomid) larvae, while caddisfly (tricoptera) larvae were the most common organisms observed on the river substrates during June. Caddisfly larvae were also the most common organisms on the November river substrates. The November discharge canal substrates were not recovered. In general, there was little difference in the size or composition of benthic populations between upstream and downstream locations.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Table 24.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1986, as reported by Iowa Electric, were somewhat less than those observed in 1985. Daily counts conducted by DAEC station personnel indicated a total of 500 fish were impinged during 1986. Highest impingement rates continued to occur during the winter. During the months of January, February, and March, 376 fish were removed from the trash baskets. The month with the highest impingement rates was January, when 134 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

Asiatic Clam Survey

In recent years several power generation facilities have experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (*Corbicula* sp.). Although this clam is common in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy Center. _Corbicula_ has not been collected from the Cedar River in the vicinity of the DAEC during the routine Cedar River monitoring program, which was implemented in April of 1971. A single _Corbicula_ was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because _Corbicula_ has been collected on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No _Corbicula_ were collected during the 1981 to 1985 investigations.

The _Corbicula_ surveys conducted during 1986 continued to be negative. Samples were taken on April 11, May 9, and October 1, 1986. During the April survey, 10 Ponar dredge samples were collected in the area between the bar screens and the traveling screens at the intake. Additional dredge samples, two in the discharge canal and in each of the cooling tower exit basins, were collected, and a visual inspection was made of the discharge canal shoreline. Dredge samples were collected from the river in May and October upstream and downstream of the station. No Asiatic clams were present in any of the dredge sampling, nor were any of these organisms observed during visual inspections of the shoreline along the river and discharge canal, and around the base of the cooling towers.

DISCUSSION AND CONCLUSIONS

In general, the results of the studies conducted on the Cedar River during 1986 were compatible with those of previous years, and continue to support earlier conclusions that operation of the Duane Arnold Energy Center has a minimal impact on the limnology and water quality of the river. Station operation resulted in temperature increases in the discharge canal, ranging from 1 to 18°C (1.8 to 32.4 °F), but downstream temperatures were rarely more than 1°C (1.8°F) above ambient. Even within the mixing zone (Station 3), ΔT values never exceeded 4°C (7.2°F), and did not adversely impact the indigenous biota of the Cedar River. Several other parameters, i.e., dissolved solids, hardness, phosphate, nitrate, chloride, iron, and other heavy metals were usually present in higher concentrations in the discharge canal than at upstream locations, due to reconcentration in the blowdown discharge. However, only suspended solids and hardness values were consistently higher in the downstream river, and increases downstream of the mixing zone were minimal. Sulfate concentrations were markedly higher in the discharge canal and within the mixing zone than upstream, due to the addition of sulfuric acid for pH control in the cooling water. Downstream values were not sufficiently high to adversely impact the river biota.

During the 1986 study, only two parameters, temperature and copper, were ever observed in the river samples at levels in excess of the Iowa Class "B" water quality standards.[16] The high copper values could not be attributed to the operation of the Duane Arnold Energy Center.

As in previous years, the operation of the Duane Arnold Energy Center appeared to have an insignificant impact on the fish or other aquatic organisms found in the Cedar River. Fish impingement rates continued to be minimal and were far below levels that would adversely effect the river fishery.

The benthic community of the Cedar River in the vicinity of the Duane Arnold Energy Center is characterized by low diversity and productivity, but this condition is not related to the operation of the station or poor water quality. The shifting sand and silt substrate present both above and below the plant is not conducive to the development of a diverse and productive benthic community. When artificial benthic substrates (Hester-Dendy) are placed in the river, similar diverse populations develop, both upstream and downstream of the station. Runoff from agricultural land and the resultant silt deposition on the river bottom appears to be the major factor limiting the development of bottom organisms.

As in previous years, the effects of agricultural activities and seasonal and climatic conditions were evident, and were similar to conditions observed in other Iowa rivers. During 1986, mean flows in the Cedar River were well above normal and nearly twice as great as those present in 1985. Surprisingly, levels of some parameters, which are frequently related to river flow, such as turbidity, suspended solids, and hardness, exhibited little variation over the two year period. Average turbidity values of 30 and 33 NTU were observed upstream of the station in 1985 and 1986, respectively (Table 26), while average suspended solids levels were actually higher during 1985 (79 mg/L) than in 1986 (63 mg/L). On the other hand, hardness values, which are traditionally expected to be higher during low flow periods, when bank storage and ground water inputs make up a greater proportion of river flow, were actually greater during 1986 (285 mg/L) than during 1985 (237 mg/L). The Cedar River has one of the highest base flows of any Iowa river. As a result, the major contribution made by ground water to the flow in the Cedar River may be, at least in part, responsible for these conditions.

The higher river flows present in 1986 appeared to be less suitable for the development of algal populations than was the case during 1985. This was especially evident during the summer months. In 1985, high dissolved oxygen, pH, carbonate alkalinity, and BOD values were consistently present during the summer months when river flows were low and large algal populations were present. In 1986, summer flows were far higher and levels of the above mentioned parameters were substantially less.

As in previous years, increased turbidity, suspended solids, phosphate, ammonia, iron, BOD, and coliform levels were frequently observed at the beginning of periods of rainfall or snowmelt and subsequent runoff. This condition is consistent with the importance of "nonsource point" input from agricultural land runoff to the water quality of the Cedar River, as well as other midwestern rivers.[18]

The effects of agricultural practices in the Cedar River basin are especially evident when the trends in nitrate concentrations observed in the river since the inception of the study in 1972, are reviewed. From 1972 to 1983, nitrate nitrogen concentrations increased from an annual average of 0.23 to 8.6 mg/L (Table 26). This increase was most apparent when years with similar mean flows were compared, and was especially marked when annual nitrate loading values (obtained by multiplying mean annual concentrations by cumulative runoff) were compared (Table 27). The trend was reversed in 1984 and 1985, primarily due to reduced application of nitrogen-based fertilizer during 1983, when the government's Payment in Kind (PIK) program resulted in substantial reductions in the acreage of land planted in corn. A return to higher nitrate levels was apparent in 1986 when the average nitrate nitrogen value increased by 2 mg/L to 6.8 mg/L

Changes in agricultural practices are also the likely cause of the reductions in total coliform concentrations observed in the river in 1985 and 1986, when average annual values of 2,534 and 2,138 organisms/100 ml, respectively, were observed upstream of the Duane Arnold Energy Center at Lewis Access (Station 1). These concentrations are markedly below the annual average of 18,783 organisms/100 ml observed during the high flow year of 1973, and 8,829 organisms/100 ml observed in 1978, a relatively low flow year. These reductions in coliform levels appear to be related to a shift to fewer and larger livestock operations and the resultant change in manure disposal operations. Smaller operators traditionally spread manure over snow or bare ground in the winter or early spring, while large operators generally "knife" wastes into the soil or lagoon wastes, which result from confinement feeding operations.[19] Discharge of treated domestic wastes from upstream sources appeared to have little effect on coliform numbers, since highest values usually occurred at the beginning of increased runoff, while low values accompanied periods of reduced river flow.

Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1986

Date	Mean Monthly Discharge (cfs)	Percent of 1951-1980 Median Discharge
January	2,466	236
February	2,501	205
March	14,120	266
April	8,333	143
May	10,612	250
June	8,128	191
July	6,838	209
August	2,664	132
September	3,341	187
October	10,570	707
November	4,464	242
December	3,641	290

*Data obtained from U.S. Geological Survey records

Table 2

Temperature (^{o}C) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0	0	18	4	4
Jan 28	0	0	0	1	1
Feb 11	1	1	9	1	1
Feb 25	0	0	8	4	0
Mar 11	2	2	15	3	3
Mar 25	7	8	12	8	9
Apr 08	12	11	17	12	11
Apr 22	10	10	23	10	10
May 06	18.5	17.5	22	18	18
May 20	15	16	20	16	14
Jun 10	22	23	25	24	22
Jun 24	22	23	28	24	22
Jul 08	24	24	31	25	25
Jul 22	26	26	29	27	26
Aug 05	22	23	28	24	23
Aug 19	25	25	27	26	25
Sep 02	21	21	22	21	20
Sep 16	17	16	17	16	16
Oct 07	13	13	13	13	13
Oct 21	12	12	24	13	11
Nov 04	8	8	20	9	8
Nov 18	1	1	2	1	2
Dec 02	2	2	5	3	3
Dec 17	1	1	1	1	1

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling During 1986

Date	ΔT (°C) U/S River (Sta. 2) vs. Discharge Canal (Sta. 5)	ΔT (°C) U/S River (Station 2) vs. D/S River (Sta. 3)	ΔT (°C) U/S River (Sta. 2) vs. D/S River (Sta. 4)	Station Output (% full power)
Jan 14	18	4	4	65
Jan 28	0	1	1	79
Feb 11	8	0	0	75
Feb 25	8	4	0	77
Mar 11	13	1	1	84
Mar 25	4	0	1	<1
Apr 08	6	1	0	44
Apr 22	13	0	0	90
May 06	4.5	0.5	0.5	48
May 20	4	0	0	57
Jun 10	2	1	1	3
Jun 24	5	1	1	90
Jul 08	7	1	1	91
Jul 22	3	1	1	99
Aug 05	5	1	1	96
Aug 19	2	1	1	98
Sep 02	1	0	0	99
Sep 16	1	0	0	66
Oct 07	0	0	0	<1
Oct 21	12	1	1	77
Nov 04	12	1	1	98
Nov 18	1	0	0	94
Dec 02	3	1	1	91
Dec 17	0	0	0	<1

Table 4

Turbidity (NTU) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	4	5	5	4	3
Jan 28	4	4	3	4	4
Feb 11	8	8	13	10	10
Feb 25	5	2	2	6	3
Mar 11	43	70	66	71	75
Mar 25	46	44	42	47	45
Apr 08	43	43	53	42	40
Apr 22	24	24	46	22	23
May 06	33	47	60	29	34
May 20	44	42	86	40	40
Jun 10	51	51	53	53	54
Jun 24	160	180	340	180	180
Jul 08	43	49	140	70	51
Jul 22	36	43	110	48	36
Aug 05	35	36	44	50	36
Aug 19	23	25	32	26	26
Sep 02	21	20	25	20	19
Sep 16	18	21	20	24	21
Oct 07	71	80	58	78	76
Oct 21	31	30	91	32	29
Nov 04	16	20	42	20	19
Nov 18	13	15	18	14	16
Dec 02	14	14	38	16	15
Dec 17	4	5	7	4	4

Table 5

Total Solids (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	420	420	1200	470	420
Jan 28	380	380	740	410	400
Feb 11	390	360	760	380	370
Feb 25	390	380	890	430	380
Mar 11	300	350	1000	370	360
Mar 25	380	370	370	380	340
Apr 08	430	410	540	440	430
Apr 22	390	380	1200	390	390
May 06	430	470	1500	460	460
May 20	470	440	1100	430	440
Jun 10	490	470	440	460	450
Jun 24	620	640	700	690	630
Jul 08	540	510	1800	520	560
Jul 22	420	450	1800	700	500
Aug 05	360	360	800	520	400
Aug 19	360	330	1100	560	390
Sep 02	370	380	380	390	360
Sep 16	380	370	380	380	380
Oct 07	490	500	460	470	470
Oct 21	450	480	1040	440	400
Nov 04	420	430	1200	520	430
Nov 18	400	420	430	430	450
Dec 02	390	380	930	510	400
Dec 17	400	390	480	410	390

Table 6

Dissolved Solids (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	380	380	1000	430	380
Jan 28	360	360	690	390	350
Feb 11	320	320	710	350	340
Feb 25	340	330	850	380	350
Mar 11	220	210	850	220	220
Mar 25	290	270	300	260	280
Apr 08	310	300	440	340	340
Apr 22	260	270	1000	300	290
May 06	330	320	1260	360	330
May 20	360	340	940	360	340
Jun 10	370	350	340	350	330
Jun 24	350	350	380	340	300
Jul 08	350	370	1500	380	410
Jul 22	330	320	1400	540	370
Aug 05	240	220	570	350	250
Aug 19	220	220	860	400	280
Sep 02	240	230	250	250	230
Sep 16	300	260	290	280	280
Oct 07	340	350	350	340	340
Oct 21	370	420	710	370	310
Nov 04	350	340	1100	440	350
Nov 18	360	370	380	370	390
Dec 02	350	340	880	430	440
Dec 17	390	370	450	380	370

Table 7

Suspended Solids (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	10	10	14	14	14
Jan 28	14	14	20	12	12
Feb 11	<1	<1	24	<1	2
Feb 25	2	<1	10	8	6
Mar 11	82	130	80	140	140
Mar 25	54	44	26	62	42
Apr 08	74	76	70	86	72
Apr 22	38	38	68	38	38
May 06	68	110	90	76	78
May 20	72	76	100	56	72
Jun 10	90	98	90	94	110
Jun 24	280	280	220	270	250
Jul 08	88	110	250	94	98
Jul 22	66	90	350	130	96
Aug 05	88	110	110	120	90
Aug 19	94	92	130	110	82
Sep 02	90	110	80	94	98
Sep 16	56	64	48	52	54
Oct 07	120	100	100	130	100
Oct 21	42	62	310	56	54
Nov 04	28	44	66	40	42
Nov 18	26	26	28	36	24
Dec 02	32	30	26	36	24
Dec 17	8	5	13	8	7

Table 8

Dissolved Oxygen (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

	Sampling Locations				
Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	13.7	10.9	11.6	11.0	12.1
Jan 28	13.3	13.6	13.3	13.1	12.8
Feb 11	12.6	12.3	12.5	12.6	13.1
Feb 25	12.4	12.3	14.2	11.5	13.6
Mar 11	11.5	11.2	9.6	11.2	11.4
Mar 25	11.2	11.1	10.8	11.2	11.1
Apr 08	10.5	10.4	9.1	10.5	10.4
Apr 22	12.5	12.5	8.6	12.8	12.6
May 06	8.6	10.5	7.8	10.5	10.5
May 20	9.0	8.9	8.4	8.6	8.6
Jun 10	8.2	8.3	8.0	8.2	7.9
Jun 24	7.5	7.4	7.0	7.4	7.4
Jul 08	8.2	8.1	6.3	8.0	7.6
Jul 22	8.9	8.9	7.0	8.5	8.1
Aug 05	9.5	9.3	6.2	8.8	9.4
Aug 19	10.7	11.2	6.6	10.0	10.0
Sep 02	9.5	9.8	9.4	9.8	9.7
Sep 16	10.3	10.5	10.7	10.8	9.9
Oct 07	9.5	9.2	10.1	9.6	9.4
Oct 21	9.9	9.8	7.8	9.7	9.8
Nov 04	14.4	14.4	10.5	14.0	14.1
Nov 18	15.6	15.7	15.6	15.7	15.3
Dec 02	14.7	14.6	11.0	14.8	14.6
Dec 17	15.7	15.7	12.9	15.4	15.7

Table 9

Carbon Dioxide (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	40	21	11	18	16
Jan 28	7	22	5	8	7
Feb 11	17	20	6	15	16
Feb 25	17	17	2	15	16
Mar 11	10	14	4	15	15
Mar 25	9	22	9	23	17
Apr 08	2	<1	<1	<1	<1
Apr 22	<1	<1	4	<1	<1
May 06	<1	2	4	2	2
May 20	4	4	2	4	4
Jun 10	2	<1	<1	<1	<1
Jun 24	9	10	16	12	13
Jul 08	<1	<1	2	<1	<1
Jul 22	<1	<1	3	1	<1
Aug 05	2	2	3	3	2
Aug 19	<1	1	3	1	1
Sep 02	<1	1	<1	<1	1
Sep 16	2	2	3	2	3
Oct 07	9	5	3	5	6
Oct 21	5	5	5	5	5
Nov 04	3	4	3	4	4
Nov 18	7	5	8	7	20
Dec 02	6	6	19	6	7
Dec 17	9	8	8	7	8

Table 10

Total Alkalinity (mg/L-$CaCO_3$) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	238	230	142	222	220
Jan 28	232	225	160	250	242
Feb 11	202	198	160	188	200
Feb 25	234	230	162	222	232
Mar 11	136	125	102	124	126
Mar 25	146	140	118	124	138
Apr 08	194	192	258	188	188
Apr 22	202	200	118	204	206
May 06	190	202	62	206	200
May 20	182	184	96	180	182
Jun 10	210	208	204	204	206
Jun 24	172	172	102	168	166
Jul 08	178	186	112	184	196
Jul 22	218	220	78	184	210
Aug 05	152	128	68	140	142
Aug 19	140	138	116	130	136
Sep 02	142	146	142	144	142
Sep 16	164	164	162	160	160
Oct 07	*	*	*	*	*
Oct 21	*	*	*	*	*
Nov 04	226	227	122	211	220
Nov 18	232	232	230	230	230
Dec 02	223	214	154	214	210
Dec 17	244	244	240	242	244

*Laboratory accident

Table 11

Carbonate Alkalinity (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	<1	<1	<1	<1	<1
Jan 28	<1	<1	<1	<1	<1
Feb 11	<1	<1	<1	<1	<1
Feb 25	<1	<1	<1	<1	<1
Mar 11	<1	<1	<1	<1	<1
Mar 25	<1	<1	<1	<1	<1
Apr 08	6	6	22	6	6
Apr 22	8	8	<1	8	7
May 06	12	<1	<1	<1	<1
May 20	<1	<1	<1	<1	<1
Jun 10	<1	8	14	10	8
Jun 24	<1	<1	<1	<1	<1
Jul 08	8	10	<1	6	8
Jul 22	6	4	<1	<1	<1
Aug 05	<1	<1	<1	<1	<1
Aug 19	2	<1	<1	<1	<1
Sep 02	6	<1	2	2	<1
Sep 16	<1	<1	<1	<1	<1
Oct 07	<1	<1	<1	<1	<1
Oct 21	<1	<1	<1	<1	<1
Nov 04	<1	<1	<1	<1	<1
Nov 18	<1	<1	<1	<1	<1
Dec 02	<1	<1	<1	<1	<1
Dec 17	<1	<1	<1	<1	<1

Table 12

Units of pH from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	7.2	7.5	7.4	7.5	7.6
Jan 28	8.0	7.5	8.0	8.0	8.0
Feb 11	7.6	7.5	7.8	7.6	7.6
Feb 25	7.6	7.6	8.1	7.6	7.6
Mar 11	7.6	7.4	7.7	7.4	7.4
Mar 25	7.6	7.3	7.5	7.1	7.3
Apr 08	8.4	7.5	9.2	8.5	8.5
Apr 22	8.5	8.5	7.8	8.5	8.4
May 06	8.5	8.3	7.7	8.3	8.3
May 20	8.0	8.0	7.7	8.0	7.9
Jun 10	8.3	8.5	9.0	8.7	8.7
Jun 24	7.6	7.5	7.0	7.4	7.4
Jul 08	8.6	8.6	7.9	8.6	8.7
Jul 22	8.5	8.5	7.6	8.3	8.4
Aug 05	8.2	8.2	*	8.0	8.1
Aug 19	8.4	8.3	7.8	8.2	8.3
Sep 02	8.6	8.3	8.4	8.5	8.3
Sep 16	8.3	8.2	8.1	8.2	8.1
Oct 07	7.7	7.9	8.2	7.9	7.8
Oct 21	8.0	8.0	7.6	8.0	8.0
Nov 04	8.2	8.1	7.8	8.1	8.1
Nov 18	8.0	8.1	7.9	8.0	7.5
Dec 02	8.0	8.0	7.3	8.0	7.9
Dec 17	7.9	7.9	7.9	8.0	7.9

*Analytical accident

Table 13

Total Hardness (mg/L $CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	325	350	760	285	295
Jan 28	320	340	530	325	305
Feb 11	265	255	490	270	270
Feb 25	340	310	620	310	320
Mar 11	190	210	600	195	185
Mar 25	215	205	205	205	205
Apr 08	270	270	355	275	285
Apr 22	305	295	730	310	345
May 06	280	320	880	300	300
May 20	300	290	690	295	300
Jun 10	285	290	300	300	300
Jun 24	260	260	820	320	280
Jul 08	*	*	*	*	*
Jul 22	298	292	979	424	324
Aug 05	206	196	414	258	212
Aug 19	335	215	590	295	255
Sep 02	222	206	216	206	190
Sep 16	295	*	290	290	230
Oct 07	260	280	280	260	280
Oct 21	340	305	465	300	305
Nov 04	315	315	760	360	325
Nov 18	300	305	310	310	310
Dec 02	285	305	580	330	210
Dec 17	334	332	372	230	220

*Laboratory accident

Table 14

Calcium Hardness (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	225	205	480	210	205
Jan 28	200	200	335	220	215
Feb 11	185	175	335	190	200
Feb 25	220	195	400	220	230
Mar 11	130	110	395	115	110
Mar 25	140	140	150	140	130
Apr 08	195	185	255	200	200
Apr 22	205	215	475	205	200
May 06	190	190	580	190	190
May 20	195	210	435	220	195
Jun 10	205	190	215	195	200
Jun 24	160	180	340	180	180
Jul 08	*	*	*	*	*
Jul 22	205	210	635	295	225
Aug 05	112	134	234	144	114
Aug 19	125	155	360	205	130
Sep 02	122	122	118	116	116
Sep 16	155	*	115	155	120
Oct 07	130	190	190	180	190
Oct 21	210	245	340	225	215
Nov 04	220	200	520	230	215
Nov 18	210	210	210	210	210
Dec 02	205	195	420	230	210
Dec 17	225	220	260	230	220

*Laboratory accident

Table 15

Total Phosphorus (mg/L-P) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0.31	0.35	0.72	0.21	0.34
Jan 28	0.23	0.28	0.27	0.27	0.26
Feb 11	0.25	0.24	0.29	0.27	0.25
Feb 25	0.31	0.30	0.36	0.33	0.31
Mar 11	0.34	0.38	0.72	0.41	0.42
Mar 25	0.32	0.31	0.31	0.32	0.30
Apr 08	0.22	0.24	0.47	0.23	0.24
Apr 22	0.15	0.15	0.64	0.17	0.16
May 06	0.19	0.20	1.10	0.19	0.20
May 20	0.28	0.26	0.77	0.27	0.27
Jun 10	0.35	0.36	0.65	0.40	0.34
Jun 24	0.46	0.48	1.20	0.52	0.51
Jul 08	0.19	0.18	0.50	0.28	0.20
Jul 22	0.30	0.33	1.20	0.54	0.37
Aug 05	0.16	0.20	0.66	0.31	0.20
Aug 19	0.22	0.21	0.60	0.44	0.06
Sep 02	0.22	0.26	0.22	0.33	0.25
Sep 16	0.21	0.21	0.23	0.22	0.24
Oct 07	0.30	0.30	0.68	0.34	0.34
Oct 21	0.21	0.21	0.88	0.24	0.26
Nov 04	0.36	0.38	1.40	0.58	0.41
Nov 18	0.21	0.21	0.21	0.19	0.21
Dec 02	0.28	0.25	0.60	0.31	0.29
Dec 17	0.23	0.15	0.28	0.13	0.14

Table 16

Soluble Orthophosphate (mg/L-P) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

	Sampling Locations				
Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0.18	0.18	0.39	0.19	0.18
Jan 28	0.17	0.19	0.18	0.20	0.17
Feb 11	0.20	0.19	0.20	0.22	0.22
Feb 25	0.19	0.19	0.20	0.19	0.19
Mar 11	0.16	0.22	0.45	0.26	0.23
Mar 25	0.22	0.22	0.21	0.22	0.22
Apr 08	0.10	0.10	0.17	0.08	0.09
Apr 22	<0.01	<0.01	0.24	<0.01	<0.01
May 06	0.04	0.03	0.43	0.03	0.03
May 20	0.18	0.18	0.43	0.18	0.18
Jun 10	0.09	0.10	0.15	0.10	0.06
Jun 24	0.10	0.10	0.32	0.13	0.11
Jul 08	0.10	0.01	0.43	0.17	0.11
Jul 22	0.16	0.18	0.88	0.32	0.19
Aug 05	0.01	0.01	0.24	0.06	0.01
Aug 19	0.04	0.04	1.0	0.19	0.27
Sep 02	0.08	0.08	0.06	0.07	0.05
Sep 16	0.10	0.10	0.06	0.07	0.06
Oct 07	0.21	0.22	0.26	0.22	0.21
Oct 21	0.19	0.20	0.58	0.23	0.21
Nov 04	0.19	0.15	0.57	0.17	0.13
Nov 18	0.21	0.21	0.16	0.15	0.15
Dec 02	0.14	0.13	0.31	0.16	0.16
Dec 17	0.22	0.15	0.13	0.13	0.13

Table 17

Ammonia (mg/L-N) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	0.25	0.24	0.11	0.23	0.23
Jan 28	0.25	0.16	0.12	0.20	0.16
Feb 11	0.28	0.37	0.13	0.39	0.28
Feb 25	0.17	0.14	0.01	0.14	0.14
Mar 11	0.43	0.45	0.49	0.48	0.48
Mar 25	0.23	0.28	0.36	0.30	0.24
Apr 08	0.01	0.01	0.02	0.01	0.01
Apr 22	0.03	0.08	0.10	0.01	0.03
May 06	<0.01	<0.01	0.04	<0.01	<0.01
May 20	0.02	0.14	0.07	0.16	0.15
Jun 10	0.04	0.03	0.01	0.02	0.05
Jun 24	0.13	0.05	0.14	0.03	0.02
Jul 08	0.02	0.01	0.06	0.03	0.03
Jul 22	0.04	0.07	0.11	0.15	0.03
Aug 05	0.03	0.03	0.15	0.07	0.02
Aug 19	0.01	0.01	0.18	0.04	0.01
Sep 02	0.01	0.06	0.04	0.01	0.01
Sep 16	<0.01	<0.01	<0.01	<0.01	<0.01
Oct 07	0.03	0.02	<0.01	0.03	0.01
Oct 21	0.13	0.05	0.12	0.07	0.10
Nov 04	<0.01	0.01	0.07	0.02	0.01
Nov 18	0.03	0.03	0.03	0.03	0.03
Dec 02	0.04	0.04	0.22	0.08	0.04
Dec 17	0.08	0.06	0.12	0.06	0.05

Table 18

Nitrate (mg/L-N) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	5.7	5.6	10.0	6.0	5.6
Jan 28	6.4	6.5	7.9	6.8	6.7
Feb 11	6.8	6.8	7.8	7.1	7.0
Feb 25	6.0	5.9	8.6	6.4	6.1
Mar 11	5.6	4.9	12.0	5.2	4.9
Mar 25	8.6	8.3	6.4	8.3	8.4
Apr 08	8.4	8.3	9.0	8.1	8.1
Apr 22	7.3	7.2	15.0	7.4	7.4
May 06	6.3	6.5	19.0	6.5	6.3
May 20	10.0	10.0	19.0	8.9	10.0
Jun 10	8.8	8.7	7.2	8.4	8.7
Jun 24	8.3	8.1	17.0	9.5	8.2
Jul 08	7.7	7.8	21.0	11.0	8.2
Jul 22	7.5	7.4	21.0	8.0	7.6
Aug 05	3.9	3.9	12.0	5.0	4.2
Aug 19	2.5	2.4	8.7	3.8	2.9
Sep 02	2.7	2.6	2.6	2.5	2.5
Sep 16	2.6	2.4	2.4	2.4	2.4
Oct 07	7.5	7.7	6.1	7.4	7.4
Oct 21	8.6	8.6	13.0	8.9	8.5
Nov 04	7.4	7.6	18.0	9.4	7.6
Nov 18	7.9	7.9	7.9	7.8	8.0
Dec 02	7.6	7.4	9.6	8.4	8.0
Dec 17	8.3	8.5	4.6	8.3	8.4

Table 19

Total Iron (mg/L) Values from the Cedar River
Near the Duane Arnold Energy Center During 1986

Date 1986	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0.11	0.10	0.31	0.13	0.11
Jan 28	0.16	0.18	0.25	0.21	0.18
Feb 11	0.34	0.30	0.33	0.35	0.34
Feb 25	0.21	0.12	0.16	0.19	0.12
Mar 11	0.86	1.10	1.40	1.10	1.20
Mar 25	0.80	0.68	0.75	0.76	0.74
Apr 08	0.63	0.57	0.83	0.64	0.65
Apr 22	0.47	0.47	1.20	0.51	0.48
May 06	0.51	0.47	1.10	0.43	0.50
May 20	0.52	0.51	1.10	0.49	0.47
Jun 10	0.68	0.69	0.74	0.62	0.63
Jun 24	1.00	1.10	2.90	1.10	1.20
Jul 08	0.66	0.63	2.00	1.20	0.77
Jul 22	0.58	0.60	1.20	0.81	0.56
Aug 05	0.29	0.26	0.62	0.33	0.32
Aug 19	0.44	0.32	0.74	0.42	0.47
Sep 02	0.27	0.29	0.33	0.38	0.30
Sep 16	0.33	0.21	0.17	0.26	0.18
Oct 07	0.91	1.60	1.30	1.50	1.50
Oct 21	0.68	0.66	1.80	0.70	0.66
Nov 04	0.53	0.36	0.93	0.44	0.40
Nov 18	0.40	0.52	0.38	0.38	0.43
Dec 02	0.28	0.36	0.52	0.41	0.32
Dec 17	0.09	0.15	0.21	0.29	0.10

Table 20

Biochemical Oxygen Demand (5-Day in mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	<1	<1	<1	<1	<1
Jan 28	1	<1	<1	<1	<1
Feb 11	3	3	2	3	2
Feb 25	1	<1	<1	1	<1
Mar 11	6	8	5	8	8
Mar 25	3	3	3	3	3
Apr 08	2	2	2	2	2
Apr 22	4	4	6	4	4
May 06	4	5	5	4	4
May 20	2	2	5	2	1
Jun 10	3	2	2	2	3
Jun 24	4	5	10	5	5
Jul 08	4	4	9	6	5
Jul 22	5	4	12	7	6
Aug 05	12	12	15	12	12
Aug 19	10	10	17	10	11
Sep 02	6	7	7	7	7
Sep 16	8	8	8	9	8
Oct 07	2	2	2	2	2
Oct 21	2	2	4	2	2
Nov 04	2	2	4	2	1
Nov 18	2	2	2	2	2
Dec 02	1	1	2	2	2
Dec 17	<1	<1	<1	<1	<1

Table 21

Coliform Bacteria (Total, org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	1,700	900	260	2,100	700
Jan 28	1,000	2,400	160	2,100	1,200
Feb 11	2,600	2,800	140	2,000	3,100
Feb 25	900	500	100	1,100	1,300
Mar 11	1,100	1,000	9,000	900	2,000
Mar 25	500	400	400	200	600
Apr 08	2,100	1,600	900	1,500	1,100
Apr 22	600	400	1,100	1,100	500
May 06	800	200	2,000	200	700
May 20	1,500	1,100	700	1,200	5,000
Jun 10	1,000	2,000	4,000	3,000	2,000
Jun 24	5,000	2,000	6,000	4,000	4,000
Jul 08	3,000	4,000	3,000	2,000	3,000
Jul 22	1,000	2,000	2,000	*	*
Aug 05	800	500	2,000	300	2,000
Aug 19	100	300	2,000	2,000	900
Sep 02	500	500	300	200	500
Sep 16	800	400	600	500	600
Oct 07	12,000	10,000	8,000	8,000	10,000
Oct 21	2,500	6,000	5,000	1,000	4,000
Nov 04	1,900	3,200	8,000	3,100	3,000
Nov 18	3,200	2,100	6,000	2,500	2,200
Dec 02	3,800	2,800	2,000	3,300	3,400
Dec 17	2,900	1,900	600	2,100	1,500

*Unable to quantify

Table 22

Coliform Bacteria (Fecal, org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1986

Date 1986	Sampling Locations: Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	320	280	20	370	220
Jan 28	260	250	10	330	180
Feb 11	700	440	10	370	420
Feb 25	220	230	<10	150	190
Mar 11	490	400	4,900	500	400
Mar 25	80	20	30	40	80
Apr 08	310	510	290	320	390
Apr 22	30	20	100	20	40
May 06	40	10	80	30	30
May 20	360	240	300	500	100
Jun 10	900	240	300	300	600
Jun 24	1,600	2,100	3,700	2,300	3,000
Jul 08	1,100	400	*	1,000	500
Jul 22	90	90	1,000	100	100
Aug 05	80	80	*	*	<10
Aug 19	100	200	300	100	100
Sep 02	80	50	*	*	100
Sep 16	60	70	90	70	70
Oct 07	2,400	1,800	1,800	1,200	1,300
Oct 21	200	270	100	250	234
Nov 04	160	150	300	170	190
Nov 18	310	230	450	350	280
Dec 02	810	600	1,100	680	900
Dec 17	200	130	20	120	90

*Unable to quantify

Table 23

Quarterly Chemical Analysis - 1986

Station	Cl^- (mg/L)	SO_4 (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
April 8								
1. Lewis Access	21	39	<10	<10	<10	100	<1	<10
2. Upstream DAEC	20	29	<10	<10	<10	110	<1	<10
3. Downstream DAEC	21	28	<10	<10	<10	100	<1	<10
4. 1/2 Mile Below Plant	21	29	<10	<10	<10	100	<1	<10
5. Discharge Canal	24	40	<10	<10	<10	110	<1	<10
July 22								
1. Lewis Access	20	34	<10	<10	<10	110	<1	<10
2. Upstream DAEC	20	28	<10	<10	<10	140	<1	20
3. Downstream DAEC	28	140	<10	<10	<10	130	<1	<10
4. 1/2 Mile Below Plant	22	55	<10	<10	<10	120	<1	<10
5. Discharge Canal	60	700	30	<10	<10	170	<1	20
November 4								
1. Lewis Access	21	32	<20	<10	<10	80	<1	<20
2. Upstream DAEC	21	36	<20	30	<10	40	<1	<20
3. Downstream DAEC	23	140	<20	20	<10	60	<1	<20
4. 1/2 Mile Below Plant	22	44	<20	<10	<10	40	<1	30
5. Discharge Canal	47	520	40	<10	<10	130	<1	<20

Table 24

Benthic Macroinvertibrates
Collected from the Cedar River and Discharge Canal
near the Duane Arnold Energy Center

9 May to 23 June 1986

Artificial Substrate Collections

	Site 49			Site 50			Site 51			Site 61			Discharge Canal		
Taxon	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Tricoptera															
Hydropsyche sp.				10			26	22					2	-	4
Hydropsyche bidens				75			52	82					1	3	2
Hydropsyche orris				19			16	58					-	9	-
Hydropsyche phalerata				2			1	2					-	-	-
Cheumatopsyche sp.				2			2	4					-	-	1
Symphitopsyche sp.				-			-	-					-	1	-
Diptera															
Chironomidae larvae				43			36	6					41	5	44
Chironomidae pupae				-			3	-					4	-	4
Simulium sp.				5			4	2					-	3	1
Ephemeroptera															
Baetis sp.				1			-	-					-	-	-
Caenis sp.				-			2	-					13	34	44
Heptagenia sp.				-			7	-					2	3	-
Heptagenia diabasia				-			-	4					1	1	-
Heptagenia flavescens				-			-	-					-	-	3
Isonychia sp.				42			64	274					92	80	93
Stenonema sp.				6			8	-					13	12	25
Stenacron sp.				2			-	-					-	-	-
Hexagenia limbata				-			-	-					-	1	2
Tricorythodes sp.				-			3	-					1	-	1
Plecoptera															
Pteronarcys sp.				1			5	2					-	-	1
Odonata															
Argia sp.				-			-	-					-	-	1
Coleoptera															
Elmidae larvae				3			1	2					-	-	-
Gastropoda															
Physa sp.				-			-	-					6	-	-
Hirudinea				-			-	-					3	-	1
Total No. of Organisms				211			230	458					179	152	227
Total No. of Species				13			15	11					12	11	15

Note: To convert No. of organisms counted to No./m^2 multiply by 6.25

Table 24 (cont.)

Benthic Macroinvertebrates
Collected from the Cedar River and Discharge Canal
near the Duane Arnold Energy Center

1 October to 14 November 1986

Artificial Substrate Collections

	Site 49			Site 50			Site 51			Site 61			Dischar Canal	
Taxon	A	B	C	A	B	C	A	B	C	A	B	C	A	B
Tricoptera														
Hydropsyche sp.		91					21	32	20					
Hydropsyche bidens		54					25	22	56					
Hydropsyche orris		24					16	13	11					
Hydropsyche phalerata		1					-	-	-					
Cheumatopsyche sp.		1					-	2	1					
Symphitopsyche sp.		2					-	-	2					
Diptera														
Chironomidae larvae		17					2	4	4					
Simulium sp.		-					1	-	1					
Atherix sp.		-					1	-	1					
Ephemeroptera														
Heptagenia sp.		13					2	2	4					
Heptagenia flavescens		-					-	1	2					
Stenonema sp.		3					8	7	19					
Isonychia sp.		-					-	1	-					
Plecoptera														
Pteronarcys sp.		-					6	2	8					
Total No. of Organisms		206					82	86	129					
Total No. of Species		9					9	10	12					

Note: To convert No. of organisms counted to No./m^2 multiply by 6.25

Table 25

Daily Numbers of Fish Impinged at the
Duane Arnold Energy Center
January - December 1986

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5	17	0	2	0	0	0	0	3	0	0	2
2	6	6	1	3	1	0	0	0	3	0	0	1
3	3	4	4	4	0	1	1	0	0	0	0	0
4	0	0	2	0	1	0	0	0	0	0	0	0
5	0	12	6	0	0	0	0	2	1	0	0	0
6	3	4	8	0	2	0	0	0	1	0	0	0
7	1	4	0	0	0	0	0	1	0	0	0	0
8	0	12	0	1	0	0	0	1	0	0	0	2
2	4	1	4	0	0	0	0	0	0	0	0	0
10	5	1	9	1	0	0	0	1	0	0	0	1
11	5	1	8	0	1	0	0	0	0	0	0	2
12	1	2	12	0	0	0	0	0	0	1	0	0
13	8	5	1	0	0	0	0	0	0	0	1	2
14	5	2	2	0	0	0	0	0	0	0	6	1
15	7	3	3	1	0	0	0	0	0	0	0	0
16	2	1	3	1	0	0	0	0	0	0	0	0
17	2	10	1	1	1	0	0	0	0	0	0	0
18	4	4	1	0	2	0	0	0	0	0	4	1
19	7	5	1	0	0	0	1	0	0	0	0	1
20	10	8	3	2	0	0	0	0	0	0	2	0
21	7	1	1	1	1	1	0	1	0	0	0	0
22	5	4	0	0	0	0	2	1	0	0	0	0
23	2	6	1	0	0	0	0	0	0	0	0	0
24	2	1	0	0	0	3	2	0	0	0	2	3
25	3	1	9	0	0	0	0	0	0	0	3	2
26	2	4	10	0	0	0	1	1	0	0	0	3
27	2	1	11	1	0	0	1	0	0	0	0	0
28	2	6	3	0	0	0	2	0	0	0	0	2
29	2		8	1	0	0	0	0	0	0	2	0
30	9		2	1	0	0	1	1	0	0	2	4
31	22		2		0		1	0		0		7
Total	134	129	114	24	9	5	12	9	8	1	22	34

Annual Tot. 501

Table 26

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream from the Duane Arnold Energy Center*
1972-1986

Year	Mean Flow (cfs)	Turbidity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD_5 (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7
1973	7,900	28	0.84	0.36	1.5	4.0
1974	5,580	29	2.10	0.17	4.2	4.7
1975	4,206	58	1.08	0.33	2.8	6.5
1976	2,082	41	0.25	0.25	2.8	7.3
1977	1,393	15	0.33	0.52	2.9	6.5
1978	3,709	23	0.26	0.22	4.4	3.3
1979	7,041	26	0.29	0.12	6.6	2.5
1980	4,523	40	0.34	0.19	5.4	4.3
1981	3,610	33	0.77	0.24	6.0	6.5
1982	7,252	43	0.56	0.23	8.0	5.1
1983	8,912	22	0.25	0.10	8.6	3.3
1984	7,325	40	0.32	0.10	5.9	3.9
1985	3,250	30	0.31	0.11	4.8	6.7
1986	6,475	33	0.26	0.10	6.8	3.7

*Data from Lewis Access location (Station 1)

Table 27

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center*
1972-1986

Year	Mean Flow	Cumulative Runoff (in)	Turbidity	Relative Loading Values Total PO_4	Ammonia	Nitrate	BOD_5
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49

*Data from Lewis Access location (Station 1)

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